CAM CONSTRUCTION

JEPSON

CAMS

AND THE PRINCIPLES OF THEIR CONSTRUCTION

ERRATA

On page 31 the equation at the bottom of the page should read
$1\frac{7}{8}''$ or $\frac{15}{8} = \frac{2}{3} \times \pi \times R$
$\frac{15}{8} = \frac{44}{21}R \quad R = \frac{15}{8} \div \frac{44}{21} = \frac{315}{352} \quad \text{Radius} = .895 \quad \text{Dia} = 2 \times .895 = 1.79.$

On page 32 first line should read
Now draw the base circle 1.79″ diameter.

THE author has in progress a book on mechanical drawing, of which the subject "Cams" will form a part.

Also a course in advanced mechanical drawing, especially designed for use in evening schools.

CAMS

AND THE PRINCIPLES OF THEIR CONSTRUCTION

BY

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CAMS AND THE PRINCIPLES OF THEIR CONSTRUCTION

THE Cam plays an important part in the construction of many machines, such as sewing-machines of various kinds, and especially in shoe machinery. Their shapes are as numerous as the uses that they may be put to, hence the author shows only some of the more common forms, such as the Frog, Face, Cylinder, etc., etc., with the methods of constructing the same. Irregular slots may be cut into plates, or upon the edges of plates, and made to work in unison with a roll; such an arrangement may be classed as a cam. Fig. 32.

Pictorial views of cam cutting-machines in operation, made from photographs of machines owned by the United Shoe Machinery Company of Boston, are shown in Figs. 28, 29, 30, and 31.

The author is under obligation to the following named gentlemen, who have critically examined the manuscript and the drawings: William Pearce Edwards, Chief Draughtsman for the Whittier Machine Company, Boston, Mass.; H. P. Fairfield, Instructor in Mechanics, Worcester Polytechnic Institute, Worcester, Mass.; George B. Haven, Instructor in Mechanical Engineering, Massachusetts Institute of Technology, Boston, Mass.; Erastus Woodward, Mechanical Engineer, Boston, Mass.; Arthur E. Norton, Instructor in Mechanical Drawing and Mathematics, Harvard University.

The author is also under obligation to Mr. William G. Myers, of the United Shoe Machinery Company; Mr. P. T. Dodge, President of The Mergenthaler Linotype Company; and to the Becker, Brainard Milling Machine Company for allowing the use of cuts and photos of their machines.

CAMS

A cam is a portion of a machine which imparts to some other part to which it is attached regular or irregular motion regularly. It does a specified amount of work in a given space of time. The time is measured by degrees; a degree being the unit of measurement of a circle, just as feet and inches are of the rule. The complete circle contains 360 degrees, which may be divided to suit the requirements of the cam to be constructed.

For instance: we wish to lift a lever from a point *a* through a certain distance ($1\frac{1}{4}''$), and to do it in 45 degrees; to rest, at that distance from the point of starting, through 135 degrees, to return to the distance of point *a* from the centre in 30 degrees, and to remain at rest through 150 degrees, to the point of starting. Fig. 1.

SUMMARY

Work done — from a point, *a*, follower lifted $1\frac{1}{4}''$ in	45°
Resting — through	135°
Returned — to point a distance from the centre in	30°
Resting — to point of starting through	150°
Total	360°

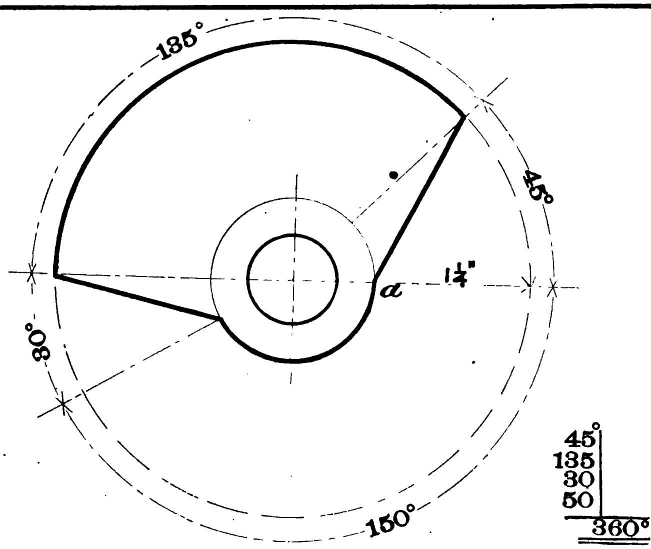


FIG. 1

The cam is usually attached to a revolving shaft; therefore revolves with it, and at the same time the follower connected with the cam starts and stops at the will of the designer. Cams are usually worked in connection with a roll which prevents the metals from rubbing together, but will allow them to roll together, as shown in most of the following figures. The size of the roll depends upon the size of the cam with which it is to work. The ordinary diameters are from $\frac{1}{2}$ to $\frac{3}{4}''$. See Fig. 18 for roll.

The relation of the follower to the driver may always be represented by a diagram of Motion, which may be given or assumed.

Fig. 2 is the diagram of Motion of the cam shown in Fig. 3.

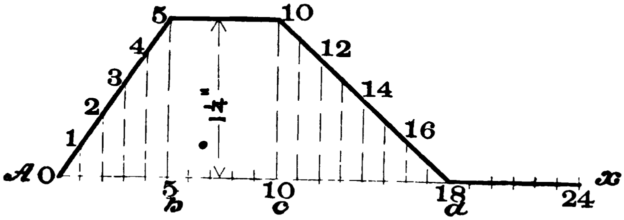


FIG. 2

The base-line A X of the diagram in Fig. 2, which corresponds to the base-circle A X of the cam in Fig. 3, may be divided into any convenient number of equal parts, say twenty-four. This will make one division equal to 15 degrees of the circle. From *a* to *b* on the base-line A X of Fig. 2 there are five divisions which correspond to five divisions of the base-circle A X of Fig. 3, or 75 degrees of the circle. The diagram calls for a rise of 1¼″ in that time in degrees. From *b* to *c* the horizontal line of the diagram, which represents a rest, is also equal to five divisions or 75 degrees. From *c* to *d* there are eight divisions which equal 120 degrees, and represent a fall to the plane of starting. From *d* to X the remaining six divisions, or 90 degrees, represent a rest to the point of starting, A. A and X, as shown in Fig. 3, represent the same point of the base-circle, and therefore of the cam.

SUMMARY

Work done — follower lifted 1¼″ in	75°
Resting — through	75°
Returned — to plane of starting in	120°
Resting — to point of starting	90°
Total	360°

Fig. 3. This base-circle may be assumed any distance from the centre of the cam, providing we assume it sufficiently far away to allow for a shaft and a hub.

We will now describe this base-circle, which will represent the base-line A X of the diagram. To complete the irregular cam line around this base-circle we will now draw another circle enclosing the cam, which must be sufficiently far from the base-circle A X to include the greatest rise of the cam diagram. This enclosing circle we will divide into twenty-four equal parts, the same number of divisions as those of the base-line A X of the Motion diagram, and to these divisions we will draw radial lines from the centre of the circles, which will intersect the base-circle A X in points which

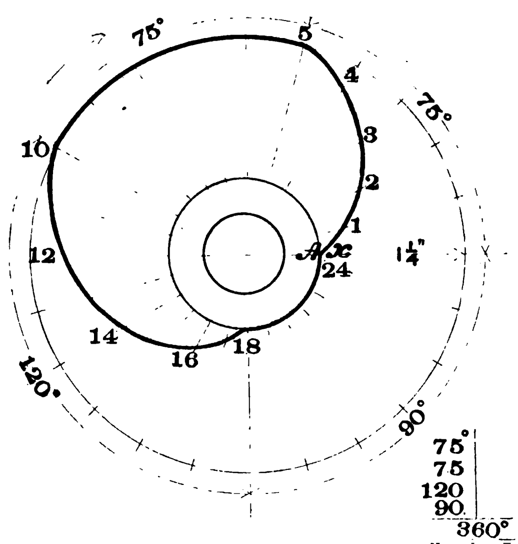


FIG. 3

we may assume to be A, 1, 2, 3, etc., as in the Motion diagram.[1] These radial lines represent the vertical lines of the diagram, and if we now measure upon these radial lines 1, 2, 3, etc. distances out from the base-circle equal to the lengths of the corresponding vertical lines 1, 2, 3, etc. of the diagram, we obtain points in the outline of the required cam.

The time of all cams is, as before stated, usually measured in degrees, but it can also be measured by any other convenient divisions of a circle, as for example, resting one quarter of the circle, rising one quarter of the circle, resting three-eighths, and falling to the plane of starting in one eighth of the circle, or by the method just employed of dividing the circle into any number of equal parts, as twelve, sixteen, twenty-four, etc.

Another most important principle to consider in designing a cam of this kind is to draw the base-circle sufficiently large to insure an easy rise and fall of the follower, as well as to allow enough stock for the hub. This is illustrated in Fig. 4, wherein for this reason it would be best to use the path A in preference to that of B, C, or D. As will readily be seen, the angle of inclination of A is much less than that of B, C, or D, although in each instance the work is done in the same number of degrees, thirty.

Cams are given various names, taken from the work with which they are connected or from the motion pro-

[1] As this cam will revolve to the right the points are numbered in the opposite direction.

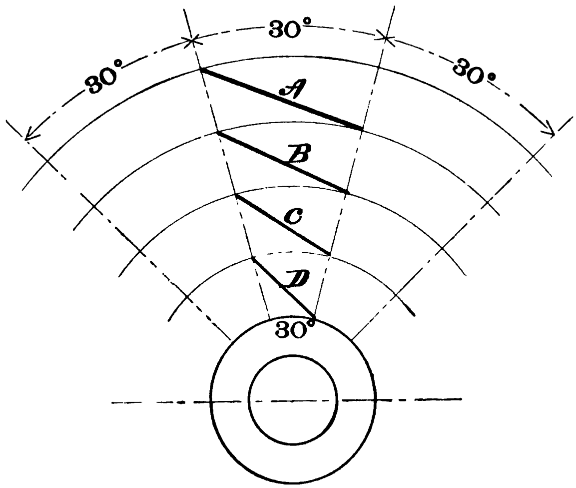


Fig. 4

duced, with reference to the shaft upon which the cam is fixed.

A cam that produces a motion in a plane parallel to the shaft is called a *Cylinder* cam. Fig. 5.

A cam producing a motion in a plane at right angles to the shaft is either a *Face*, *Frog*, or *Wiper* cam. Figs. 6, 7, and 8.

A cam, very rarely used, producing a motion oblique to the shaft is called a *Conical* cam. Fig. 9.

A cam that produces a motion that is in the arc of a circle whose centre is in the same plane as that of the shaft upon which the cam is fixed is called a *Globe* cam. Fig. 10.

In addition to the above, there are various other kinds of cams, such as *Yoke*, *Heart-Shaped*, and *Involute* cams. See Figs. 11, 12, and 13.

Two cams may be so arranged that their combined action concentrating upon one point may trace, by means of that point, any desired curve, and may even be made to form letters or words, as "Cam" in Fig. 33.

Fig. 14. A simple form which is sometimes classed as a cam is the eccentric of the steam-engine, which converts motion from a rotary to a back-and-forth, or reciprocating, motion.

The eccentric is practically a disc of any convenient diameter with a hole cut through it (not in the centre) for the shaft. If the centre of the eccentric and the centre of the shaft upon which it is placed have a differ-

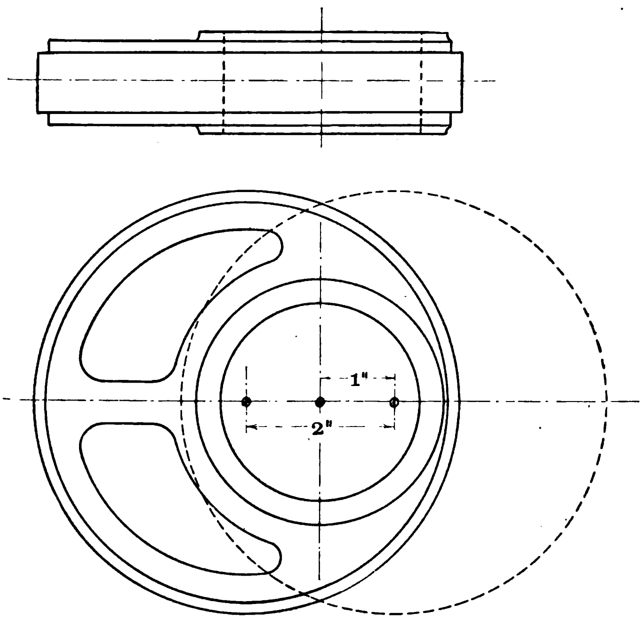


FIG. 14

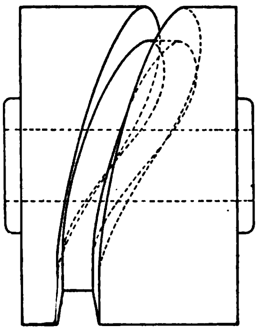


Fig. 5

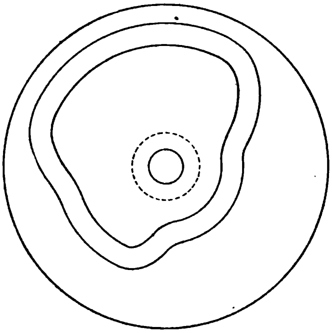


Fig. 6

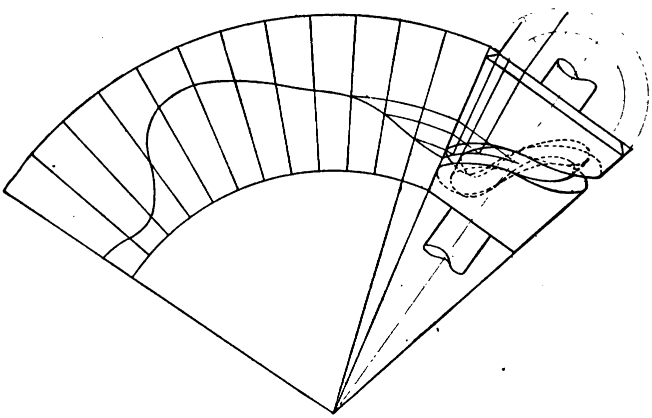


Fig. 9

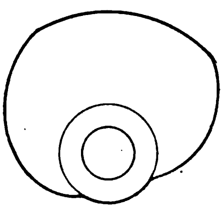


Fig. 7

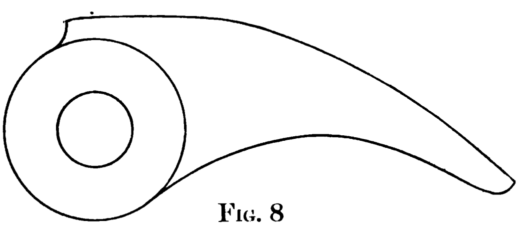


Fig. 8

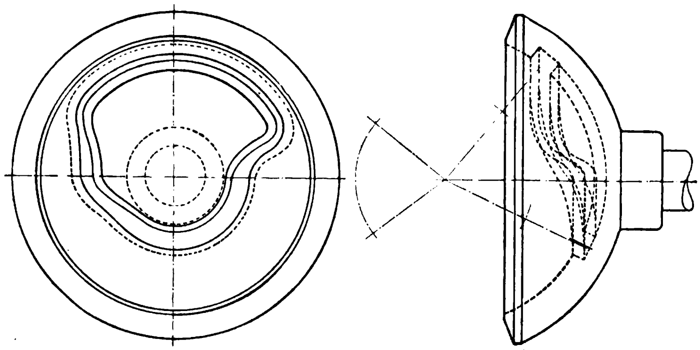


FIG. 10

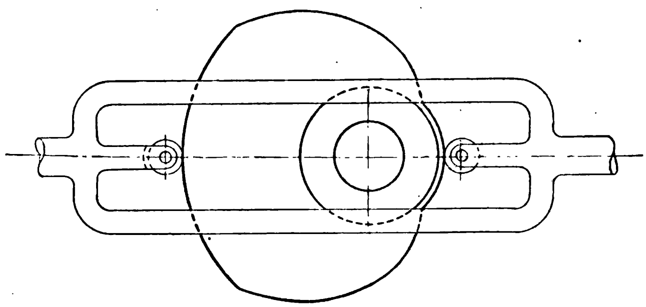


FIG. 11

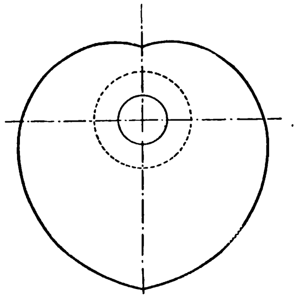


FIG. 12

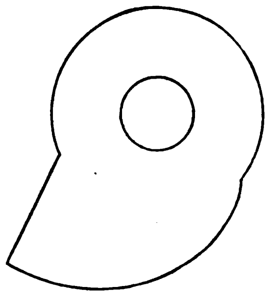


FIG. 13

ence of 1″, then in one complete revolution of the shaft the centre of the eccentric will revolve about the centre of the shaft in a circle 2″ in diameter. This diameter is referred to as the "Throw" of the eccentric.

The next cam, Fig. 15, which is heart-shaped, produces in the follower a motion of uniform velocity, but the centre-line of the follower must be straight and pass through the centre-line of the cam, as is clearly shown

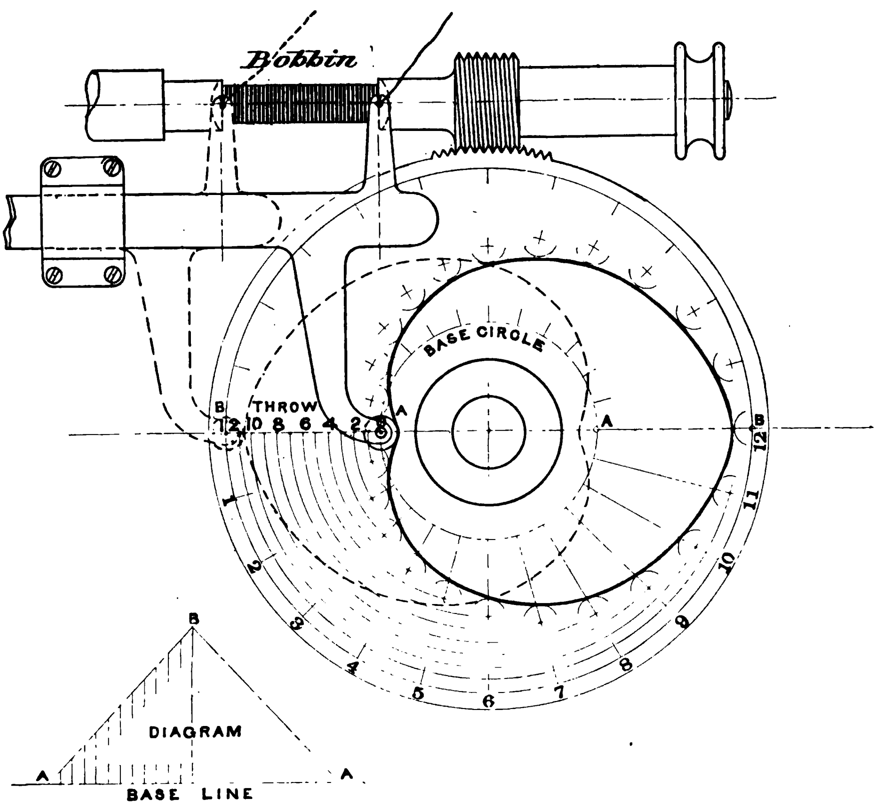


Fig. 15

by Fig. 15. The follower is often made to work in an arc of a circle, but such a condition gives approximate results only. This cam is used for winding bobbins on a sewing-machine or in any similar operation. The follower is held against the cam by a spring.[1]

To construct the cam the base and enclosing circles may be drawn. Then the distance of the throw may be divided equally by points 1, 2, 3, etc., and concentric circles may be drawn through them. Since the motion of the cam is a throw A B, in 180 degrees, and a return B A, in 180 degrees, one half the circle divided equally by the radial lines 1, 2, 3, etc. will represent the throw, and the opposite half the return; hence, only one half need be constructed, the other half may be drawn by any convenient method, such as tracing, since the two sides are symmetrical.

The next cam, Fig. 16, is a Frog cam. The principle of construction is here slightly varied; since the one essential thing in designing a cam is to construct it so that it will perform the required amount of work in a given time or in a given number of degrees, regardless of uniformity of motion, it follows that the path of the follower may be either straight, as in Fig. 1, or of any desirable curve, so long as it is continuous in the desired direction.

[1] In the majority of cases in cam construction it makes no difference whether the follower travels with uniform velocity or not. If the travel or throw is to be of uniform velocity, as in the present instance, the distance of the travel or throw A B, Fig. 15, must be divided into any convenient number of equal divisions, and the time, or that part of the circle in which the work is to be done, must be divided into the same number of equal divisions by means of radial lines. Then concentric circles drawn through the divisions of A B will intersect the corresponding radial lines in points in the required curve.

It is of importance, therefore, to use that curve which causes the least friction and wear, and will, at the same time, allow the follower to start and stop the most easily. A curve commonly used is the ogee or harmonic

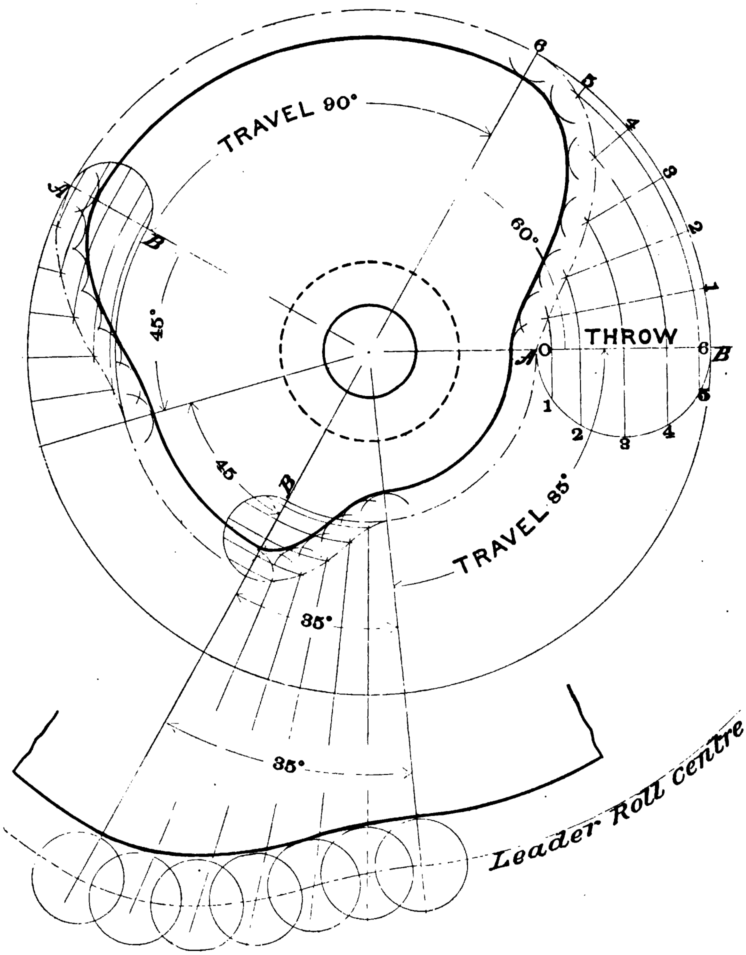


FIG. 16

curve, as illustrated in this and following figures. To construct this curve the distance of the throw is not divided equally, as in the case of the heart-shaped cam, but a semicircle is drawn whose diameter A B represents the distance of the Throw. The circumference of this semicircle is then divided into any number of equal divisions, and these divisions perpendicularly projected into its diameter. (In Fig. 16 we have used six divisions.) Concentric circles are then drawn through the points upon the diameter to intersect an equal number of equidistant radial lines contained in the required number of degrees, thus obtaining the points of the ogee or harmonic curve. A similar result may be obtained by constructing this ogee or harmonic curve upon the diagram, as shown by Figs. 19 and 26.

The line drawn through the points of the ogee curve may be taken as the centre-line of the roll. It will be readily seen that it can make no difference in results whether the cam is turned upon its centre or the roll is carried around the cam; hence we will carry the roll around the cam by drawing it in its various relative positions to the cam, and tangent to the roll in these positions we will draw the actual outline of the cam.

In this drawing we have illustrated a method of laying out a cam leader, and by referring to the pictorial views of the same Figs. 28 and 29, we shall readily see how cams are cut by the aid of the leader. The leader is usually made of some large diameter (say twelve inches). Suppose we wish to make a leader for that part of the

cam in which the most abrupt change in outline is made in the least number of degrees. By referring to the drawing it will be seen that the greater the distance from the centre of the cam, at which the path of the leader roll is assumed, the less abrupt change in outline its path will make in comparison with the outline of the cam. This is also demonstrated by Fig. 4. The diameter of the leader roll is usually made about one inch.

To find the path for the centre of the leader roll, divide the time of that part of the cam used, in this case 35 degrees, into any number of equal parts by means of radial lines of indefinite length. In this case it is already divided into six parts. Draw the centre-line of the cam cutter, which necessarily coincides with the centre-line of the cam roll, by drawing the cutter or roll in its various positions where the centre-line of the roll intersects the radial lines. This has already been done in the figure. Now we wish to find an outline of a leader and the centre-line of the leader roll, which will actually produce this particular curve in the outline of the cam. From the points of intersection of the radial lines with the cam roll centre-line already shown measure out upon each radial line the same desired distance, thus locating the centres for the leader roll. Then with the radius of the leader roll (in this case one-half an inch) draw the roll in its various positions, and tangent to it draw the outline of the cam leader. The cam leader is not a machine of itself, but is part of an adjustable attachment which may be fastened to any milling machine, which is

used by mechanics generally for the purpose of cutting cams. The illustrations, Figs. 29 and 30, show a milling machine in actual operation. The cam leader and the cam to be cut are fixed upon the same centre-line of the attachment, and by referring to the figures it will be readily seen how the operation is performed. In Fig. 28 the leader is held against the leader roll by a weight. This form of leader is called an open leader, and is used for the cutting of cams when but few of that form are required. Where many cams of the same form are to be cut, it is better and customary to use a closed leader, as shown by Figs. 29 and 30, thereby doing away with the weight, and assuring an absolutely positive motion similar to that of the face cam, Fig. 17. This figure is called a face or positive motion cam because the path of the roll is cut into the face of the cam; that is, in comparison to all frog or wiper cams this one would not require a spring or weight to keep the follower in contact with the cam; hence it is correctly called a positive motion cam.

A cam roll is then fitted into this groove, which is made a very little wider than the roll. If the roll is being driven away from the centre of the cam the inside edge of the groove acts upon and drives it. When the roll is being driven towards the centre of the cam the outside edge of the groove acts upon it. If the groove in the cam were not made a little wider than the roll, both its sides would act upon the roll and tend to drive it in both directions at once, and produce not rolling but

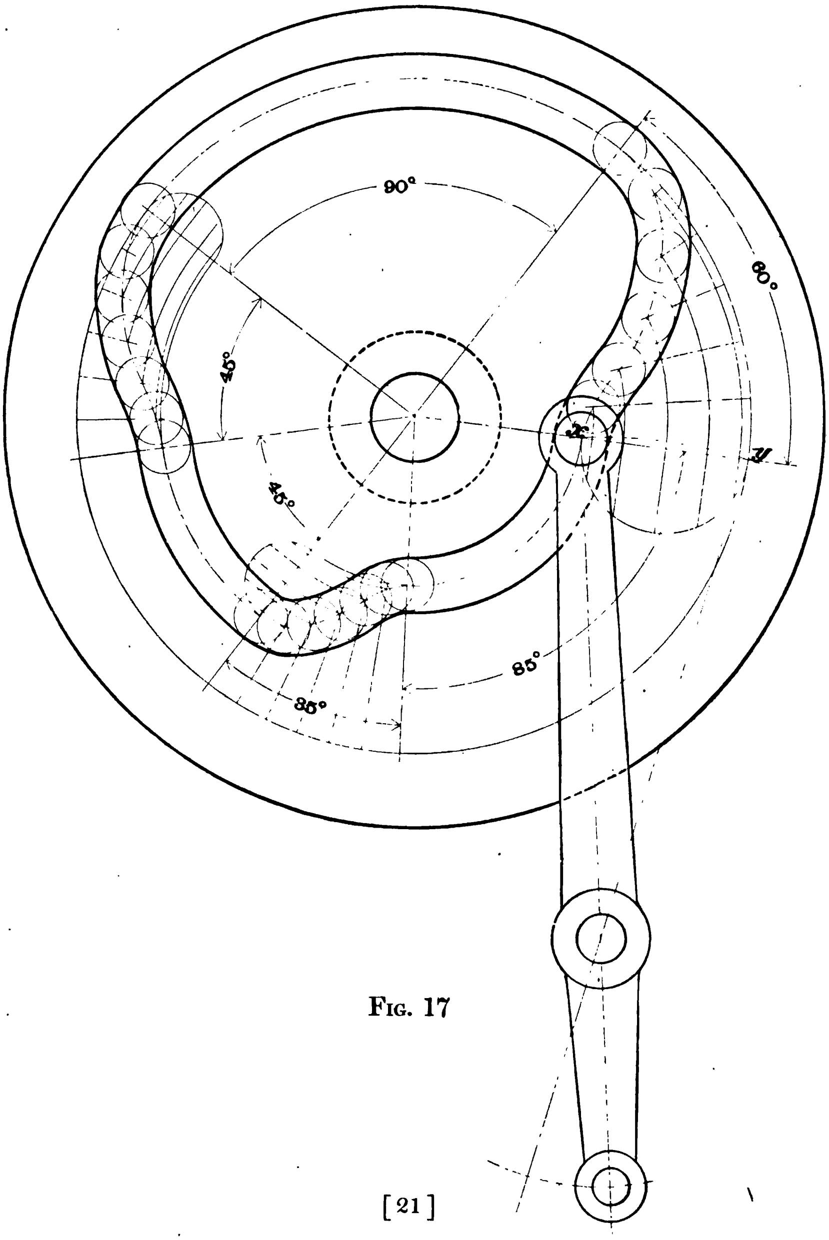


FIG. 17

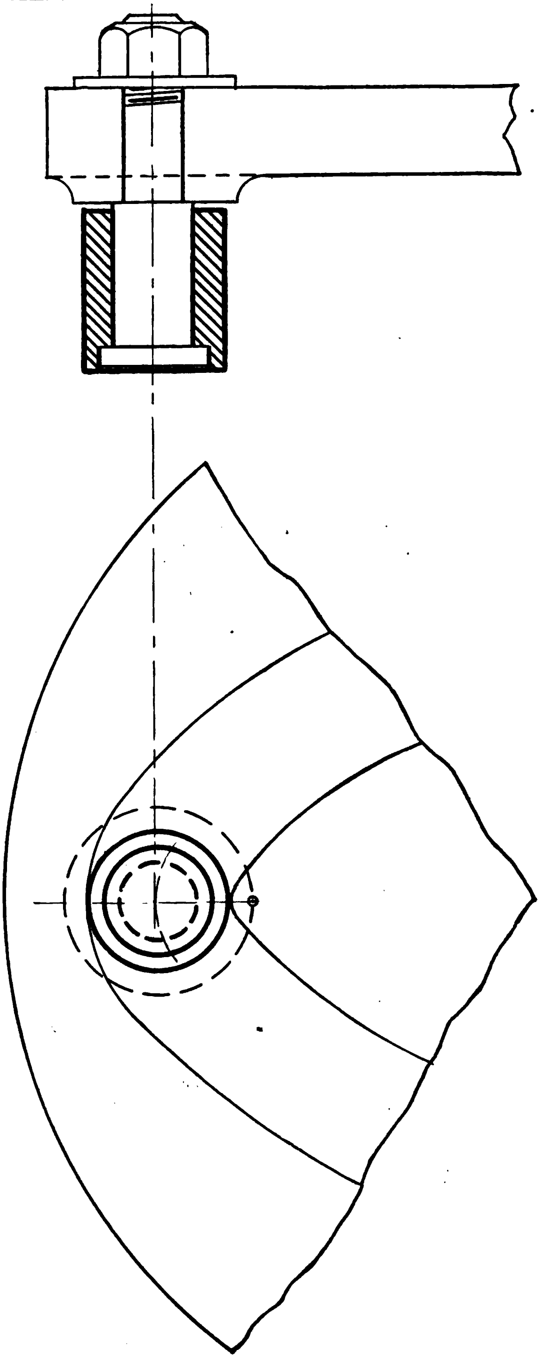


FIG. 18

sliding contact. Another important point in regard to the roll is that in making changes from one direction to another it should be made to turn upon a radius at least one-eighth of an inch greater than its own diameter.

In Fig. 18 the roll is shown its full diameter, three-quarters of an inch, six-eighths, and the radius of the curve upon which its centre turns is four-eighths of an inch. The cam can then be recut to use a roll of one inch diameter (shown in the drawing by the dotted circle), which is the limit of recutting in this case.

The method of constructing Fig. 17 is the same as that of Fig. 16, but in this case the follower is a lever which starts and stops upon the same radial line, marked X Y.

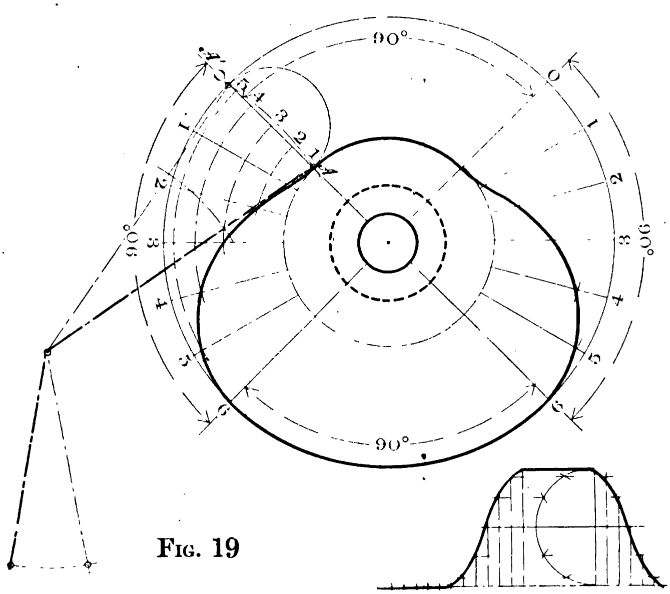


Fig. 19

Figs. 19 and 20 are two cams which do the same work in the same time in connection with a lever as a follower, but the outlines of the cams are widely different in appearance, and these drawings are made particularly

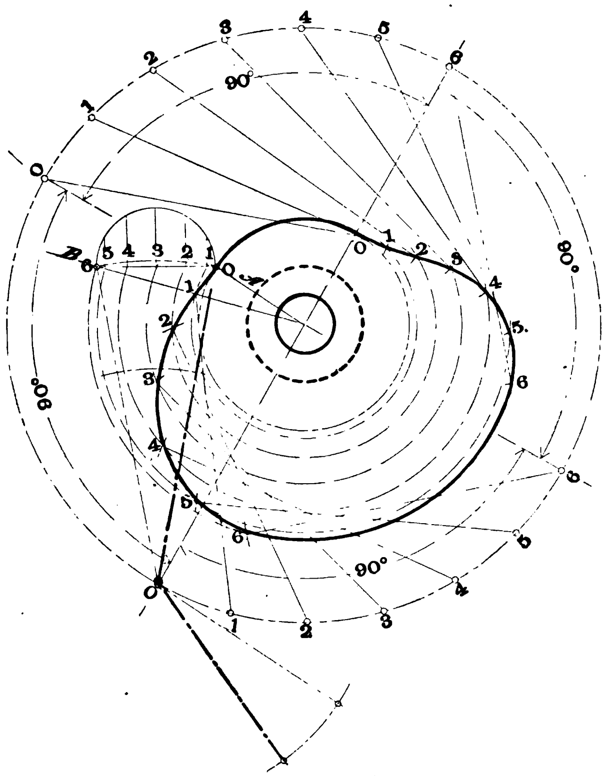


FIG. 20

to show this difference. The follower of Fig. 19, like the follower of Fig. 17, starts and stops on the same radial line A A′, while the follower of Fig. 20 starts upon one radial line A, and stops upon another radial

line B. The time of all cams is found by dividing any concentric circle, as in the case of Fig. 19; but it should be clearly understood that where a lever is used that starts upon one and stops upon another radial line the circle into which the time of the cam is divided must pass through the centre of the fulcrum of the lever, and that centre must be one of the divisions of time. The lever itself, as in Fig. 20, is carried around the cam, the results being the same as when the cam turns upon its centre. The roll may move along its path with uniform velocity or not. In this case it does not move with uniform velocity.

Fig. 21. Given the centre of a cam and the diagram of the cam, also the fulcrum of the lever to work in connection with it, and a circle x that represents the nearest distance to the centre of the cam in which the centre of the follower is to be located.

PROBLEM: To find the successive positions of the follower in its relation to the diagram as applied to the cam.

The follower is to be reduced in its throw to two-thirds that of the greatest rise of the diagram measured from the base-line x y to the highest point 14.

The base-line of the diagram we will divide into any number of equal divisions, in this case twenty-four. These divisions represent 360 degrees of the circle X. We will now assume the rod a b to be of some convenient length, perpendicular to the base-line of the diagram. For the first five divisions of the twenty-four,

that is, five twenty-fourths of the base-line, or 75 degrees of the circle, the point *a* in the rod *a b* will remain at rest, that is, from *x* to point 5. From point 5 to point 14 point *a* will move uniformly upwards in nine of the twenty-fourths, or 135 degrees, and rest at that elevation from point 14 to point 18, that is, four of the twenty-fourths, or 60 degrees. From point 18 to *y*, which equals six twenty-fourths of the base-line, or 90 degrees of the circle, point *a* will move uniformly downwards to the plane of starting, *x y*.

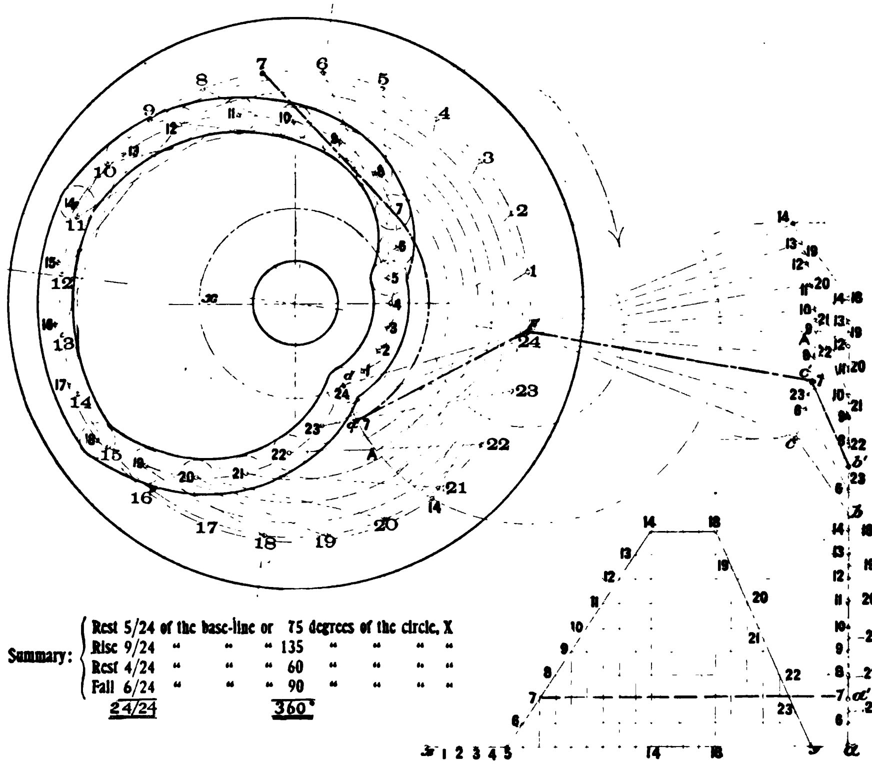


FIG. 21

As the motion is to be reduced as two is to three, the two ends, A and A′ of the lever must bear that same proportion to each other.

We will now draw the arc A′ from the fulcrum F of the lever, representing the long end of the lever, assuming its central position perpendicular to the rod *a b*. Parallel to and equi-distant from this central position, draw two lines whose distance apart equals the height of the diagram from the base-line to point 14. These lines will intersect the arc A′ in the points *c* and 14. Take two-thirds of the length of this long end of the lever, and, with the fulcrum as a centre, describe an arc A which will intersect the circle *x* already drawn in point *d*, which is the first position of the centre of the roll. The opposite end of the lever in this position is found at point *c* in the arc A′. Connect points *d* and *c* with the fulcrum, and these lines will represent the centre-line of the lever in its first position. Connect point *b* in the rod *a b* with point *c* of the lever, and this line will represent a connecting rod of which the point *c* must work in the arc A′. Although the cam is the driver and transmits its motion to the follower, for convenience in making the drawing we will consider the rod *a b* to be the driver, since, as in Fig. 20, it is more convenient to move the lever around the cam than to turn the cam upon its centre. We may then, by moving the rod *a b* through its successive positions, thereby driving the rod and lever attached to it, locate each of the successive positions of the lever and the lever roll, and from them

draw the outlines of the cam; hence through F, the fulcrum of the lever, draw a circle, and upon it locate the successive positions of the fulcrum by dividing the circle into the same number of equal divisions as those of the base-line 24.

It is proposed to emphasize point 7 and trace its motion from the diagram through the rod *a b*, the connecting rod *b c*, and the lever to its position on the cam. All other points on the cam may be traced in a similar manner. Project point 7 in the diagram into the rod *a b*, which is equivalent to lifting the rod to the position of *a′ b′*; *a′* is also marked 7. With the length of the connecting rod *b c* as a radius, from *b′* as a centre describe an arc intersecting the arc A′, thus locating *c′*, which is also marked 7; when the long end of the lever has

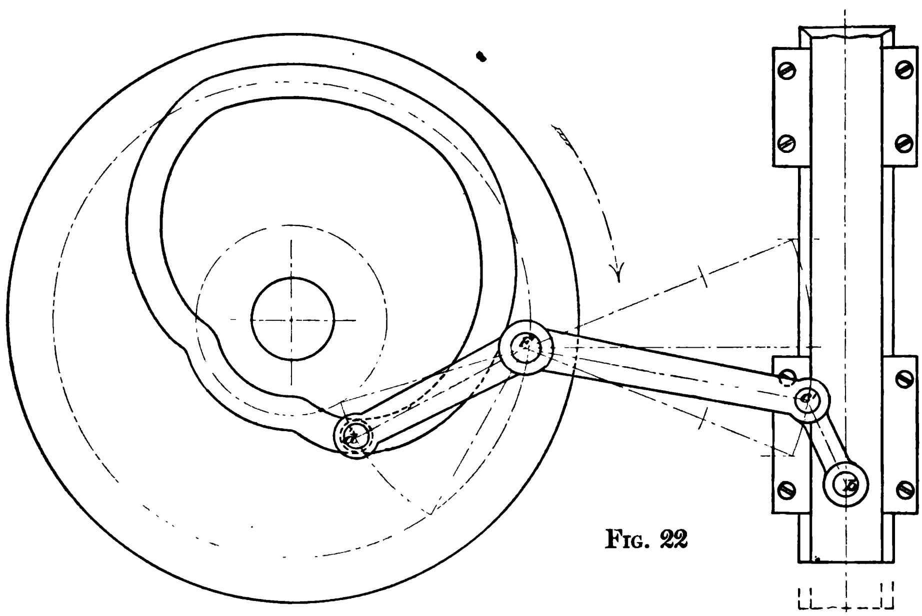


FIG. 22

moved from c to c' and the short end has moved from d to d', d' is also marked 7. Through point d' draw part of a concentric circle. With the length of the short end of the lever as a radius and the seventh position of the fulcrum as a centre, intersect this concentric circle drawn through d', thus locating the seventh position of the roll. As stated, all other positions of the centre of the roll may be located in the same manner as point 7, and the outlines of the cam drawn tangent to the roll in these positions.

Fig. 22 is a drawing of a cam and a lever, of which Fig. 21 shows the anatomy. In Fig. 22 the cam has been revolved into its seventh position. The lever is attached to a slide, the dotted lines above and below represent its two extreme positions.

INVOLUTE CAM

Fig. 23. To draw an Involute cam having a given throw in a given number of degrees.

METHOD. Suppose a cam is to raise a point $1\frac{7}{8}''$ in an arc of 120 degrees, first find the radius of a circle whose involute of 120 degrees will do that work. (An angle expressed in degrees may also be expressed in circular measure by finding its ratio to 180 degrees and multiplying the result by $\pi = 3.1416 = 3\frac{1}{7}$ approximately.)

EXAMPLE. Rise $1\frac{7}{8}''$. Angle 120 degrees. $\frac{120}{180} = \frac{2}{3}$ or $120 : 180 :: 2 : 3$ $\frac{2}{3} \times 3\frac{1}{7} = \frac{44}{21}$.

$\frac{44}{21} \div \frac{15}{8} = \frac{44}{21} \times \frac{8}{15} = \frac{352}{315} = 1.11''$ Radius. $1.11'' \times 2 = 2.22''$ diameter.

Now draw the base-circle 2.22″ diameter, and at point 0 draw a tangent of indefinite length as shown. Anywhere upon this tangent line lay off the throw $1\frac{7}{8}''$. Divide this throw into any number of equal parts, in

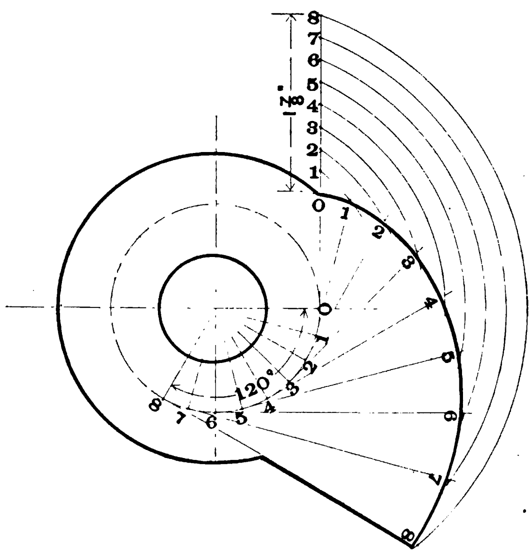


FIG. 23

this case eight, marked 0, 1, 2, 3, etc. Now from the tangent point 0 lay off 120 degrees on the base-circle and divide this arc into the same number of equal divisions, eight.

To complete the involute outline of the cam draw parts of concentric circles from the points 1, 2, 3, etc. in the tangent first drawn to intersect tangents drawn from the points 1, 2, 3, etc. in the base-circle.

Fig. 24 is somewhat similar to an involute cam, and is commonly called a lifting-toe, sometimes a wiper cam, and is used for operating the valve mechanism of river and harbor steamboats. One method of construction is as follows: The lift or rise we will suppose is 2″ and to take place in an arc of 45 degrees. Draw a base-circle of any diameter, and from a point marked 0

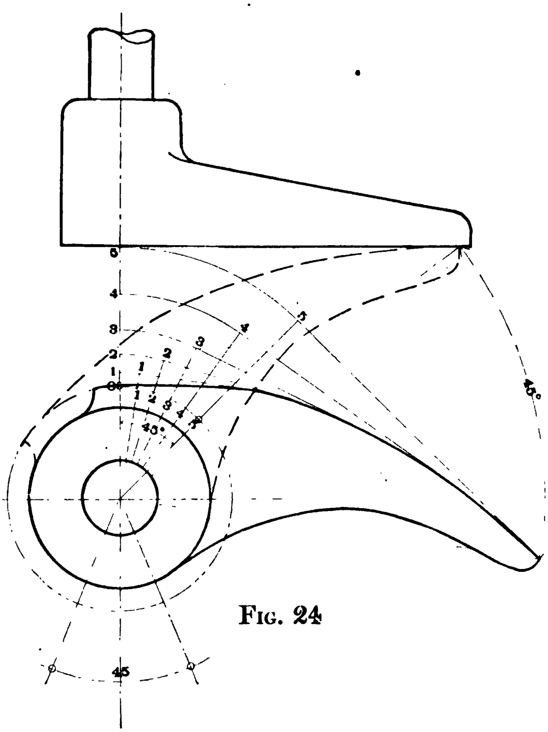


FIG. 24

erect a vertical line equal to the rise, set off on this line the points 0, 1, 2, 3, etc. *unequal* increasing distances apart, and from the same point 0 set off 45 degrees on

the base-circle and divide that into the same number of *equal* distances 1, 2, 3, etc. Then from the points in the rise draw parts of concentric circles to intersect corresponding radial lines drawn through the points in the base-circle. At the intersections of these lines draw other lines of indefinite lengths, tangent to the parts of the circles. Then tangent to these lines draw the curve of the cam.

It will be noticed that the last tangent line 5 limits the length of the lifting-toe.[1]

Fig. 25. Shows the construction of a yoke cam. Two rolls are used, as shown by the figure, working on opposite sides of the cam and so situated that the centre-line of the two rolls passes through the centre-line of the cam. Under these conditions the distance between the centres of the two rolls measured on a line passing through the centre of the cam remains constant, hence any line drawn across the cam through its centre must equal every similar line drawn across the cam.

This particular cam has a throw of a certain distance in 90 degrees, a rest of that distance through 90 degrees, falls to the plane of starting in 90 degrees, and rests at that distance from the centre to the point of starting through 90 degrees.

The throw is divided into a number of equal divisions and the travel 90 degrees is divided into the same number of equal divisions. Then radial lines to intersect

[1] The first tangent point in the curve of the cam must not be above a horizontal line drawn through point 0, or in other words 0 must remain the highest point in the curve of the cam while the cam is in this position.

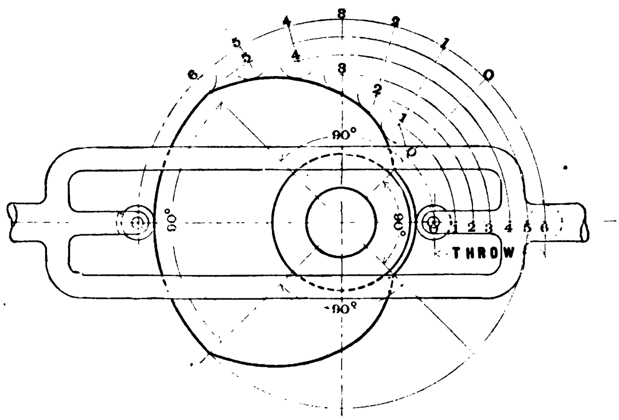


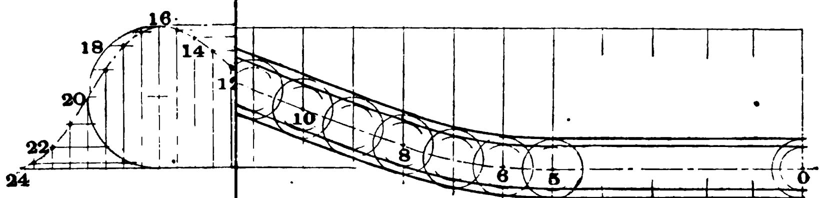
FIG. 25

concentric circles are drawn, whose intersections give the outline for the centre of the roll. It is very similar in construction to that of the heart-shaped cam. The movement is also of a regular velocity.

A cylinder cam is a cylinder with an irregular groove in its cylindrical surface. If a groove were cut into it in a plane at right angles to its axis the follower attached would have no movement; if an irregular groove were cut into it (as shown by Fig. 26) the follower would have a movement that must coincide with it. Hence any irregular line may be drawn representing the diagram of the cam, and its length upon the base-line divided into any number of equal divisions (Fig. 26 has twenty-four divisions). If the length of the diagram is equal to the circumference of the cylinder (of which the cam is to be a part), the diagram could be wrapped about the cylinder

and the line of the diagram prick-punched upon its surface. Such a line would represent the centre of the irregular motion. It is not necessary that the diagram be as long as the circumference of the cylinder. It may be of any convenient length and divided into any number of equal divisions. Now draw the side view of a cylinder of the desired diameter, whose length should be determined by the diagram which is placed at right angles to the cylinder (as shown). For instance, the length of the diagram deviates from a straight line (which we may term its base) one and one-half inches, and the roll to be used is five-eighths of an inch in diameter. Then the length of the cylinder will be one and one-half inches plus five-eighths of an inch, plus the thickness of the metal each side of the groove, say one-half an inch. The sum of these dimensions will give the length of the cylinder three and one-eighth inches; draw an end view of the cylinder and divide it into the same number of equal divisions as the base-line.

The time of this cam is to be measured in parts of a circle. From 0 to point 5 the follower would be at rest; from point 5 to point 16 (eleven divisions) it deviates from the base-line one and one-half inches, and returns to the base-line in eight more divisions to point 24, or 0. Make the path of the follower an ogee curve (as shown and described in previous drawings). The points in these curves are numbered from 5 to point 16, and from point 16 to 24, or 0. Now assume 0 to be any one of the points in the end view of the cylinder,



16
18
14
12
20
10
22
8
6
5
0
24

and mark the other points 1, 2, 3, etc. to 24, or 0. Project lines from the points in the end view of the cylinder, to intersect lines projected from the same points in the diagram, thus locating the centre-line of the irregular groove, which is equivalent to wrapping about the cylinder its actual development, marking the points by a prick-punch as previously stated. Draw another circle upon the end view, which will represent the depth of the groove; intersect this inner circle by radial lines drawn from the points upon the outer circle, thus dividing the inner circle into proportional divisions. From the points thus obtained on the inner circle project lines to intersect lines drawn from the same points in the diagram, thus obtaining the centre-line for the bottom of the roll. For all practical purposes the centre-line would be sufficient, but in this case we wish to make a more complete drawing and project the apparent diameters of the roll upon the cylinder. To accomplish this, make an actual development of the cylinder cam (as shown), and locate by projection the different centres of the roll in their true positions upon the elements containing them. From these centres draw circles representing the diameters of the roll (top and bottom, if the roll is taper), and draw a smooth curve tangent to these circles; these curves will intersect the elements drawn through the centres of the roll in points marked *a*, *b*, *c*, etc. Project back the points *a*, *b*, *c*, etc. upon the same elements upon the cylinder, and through these points draw a smooth curve, thus completing the drawing of

the cylinder cam; if the developed surface were wrapped about the cylinder the two curves must coincide.

A conical cam shown in illustration, Fig. 9, should be constructed in a similar manner, the method being applied to a cone instead of a cylinder. This may be readily seen by referring to the figure. A conical cam produces a motion oblique to the shaft.

Fig. 27. It has been stated frequently in the text that the path of the follower of a cam should be so formed that it will start and stop easily, regardless of the uniformity of its motion. Such a form is the ogee curve shown in Figs. 16 and 26. The speed of the follower travelling on such a curve coincides very nearly with the speed of a falling body. A body falling from rest has no initial velocity, but has a correspondingly increasing velocity under the action of gravity until it reaches the ground. Similarly, if a body is thrown upwards with the same velocity it had on striking the ground, it will come to rest at a height equal to that from which it was dropped, and its upward motion will be the reverse of the downward motion, that is, uniformly retarded. Therefore it is reasonable to suppose, in designing a cam, that the motion of the follower should conform to the same law of gravity, and have a uniformly accelerated motion for half the distance, and a uniformly retarded motion through the other half.

A body free to fall descends through spaces during the successive units of time, proportionally to the odd numbers 1, 3, 5, 7, 9, etc., and the total space passed

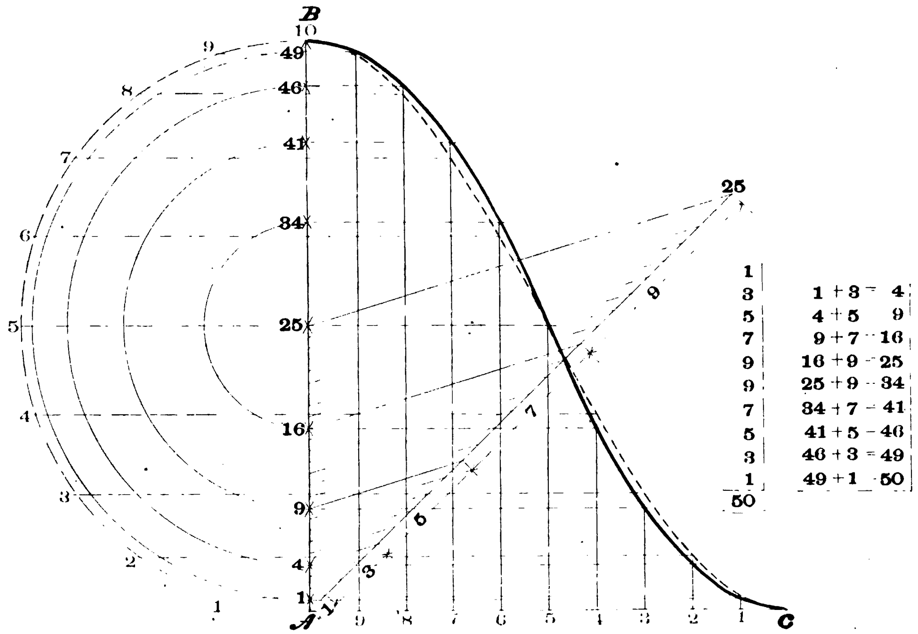


FIG. 27

through equals the sum of these spaces 1, 3, 5, 7, 9, etc. EXAMPLE: Suppose we wish to raise a point from A to B in a given time A C. Proceed as follows: Divide the time-line A C into any number of equal parts, as ten; then sum up the relative spaces to be passed over by the follower, increasing through five spaces and decreasing by the same law through the remaining five; hence $1+3+5+7+9+9+7+5+3+1=50$, giving 50 in this case. Next obtain the relative spaces passed through from the start at the end of each interval by adding the spaces passed through in the interval to all preceding

spaces, the result of which is shown in the table at the right of the figure, where the relative space passed over at the end of the second interval is four, of the third interval, nine, and so on. Now divide the line A B into fifty parts, and mark the divisions corresponding to the numbers in the column 1, 4, 9, 16, etc. Through these points draw horizontal lines, and note the points where they intersect the vertical lines drawn through the corresponding divisions of the time-line A C. (It is the divisions that correspond and not the figures that mark the divisions.) By drawing a smooth curve through these points, shown by a full black line in the figure, we produce the gravity curve. In designing cams to revolve rapidly, and to give motion with the least shock, the gravity curve should be used. The dotted red line shows the ogee or harmonic curve, which is commonly used; the black line shows the gravity curve.

WRITING CAM

Fig. 33. To produce a motion similar to the line of a written word the general principles involved are the same as for the designing of any cam; only, in this case, two cams working in unison must be used,— one to produce a back-and-forth, or reciprocating motion, while the other produces an up-and-down motion, — the two acting together upon the same point and at the same time, producing any required curve, such as a written word.

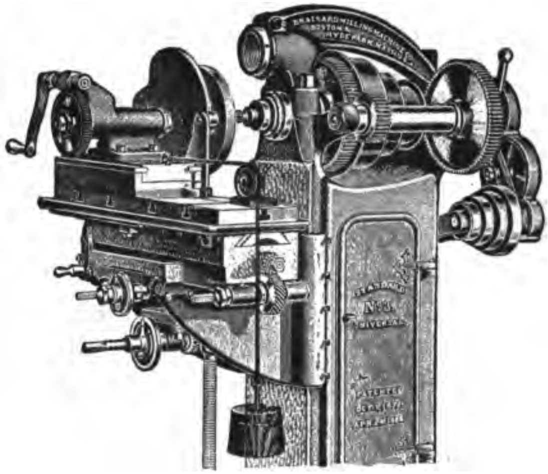


FIG. 28 — Showing open leader

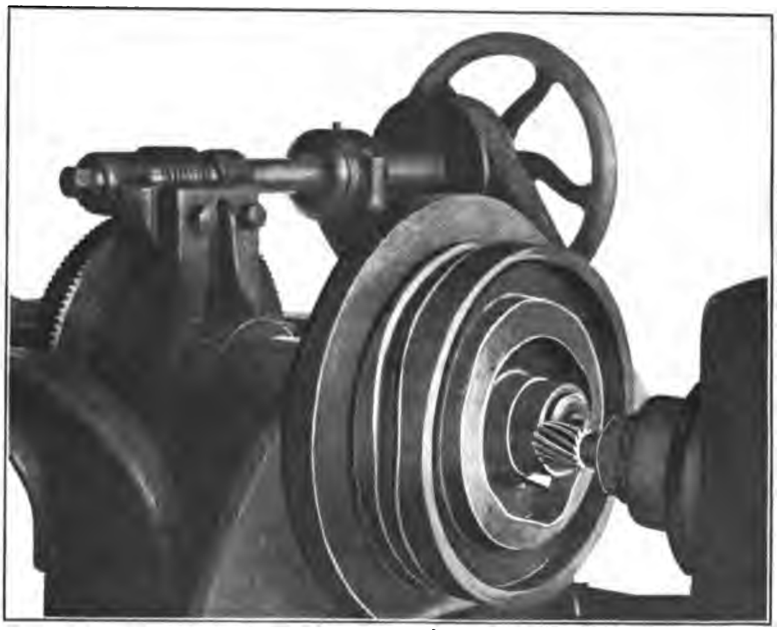


FIG. 29 — Closed leader

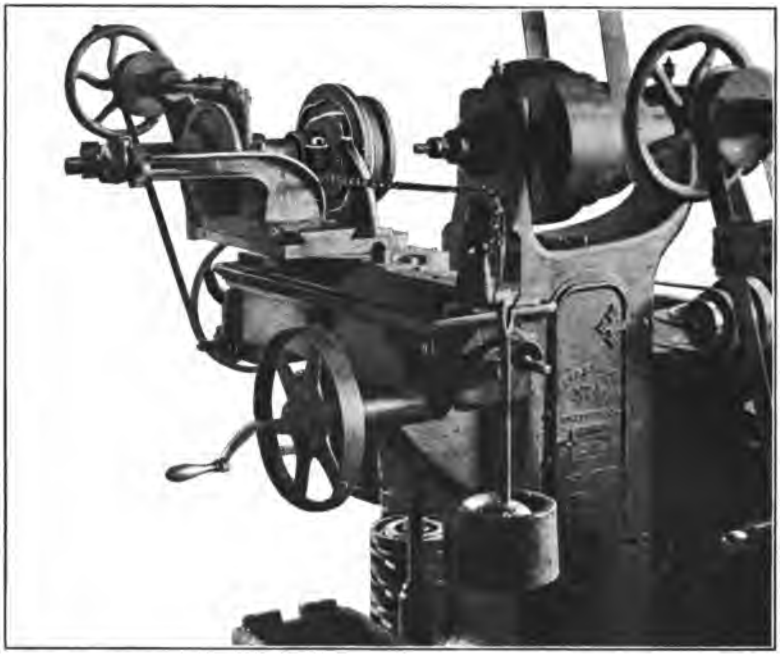


FIG. 30 — Both closed leader and weight are used to ensure a more positive motion

FIG. 31 — Cam cutting attachment connected to a lathe

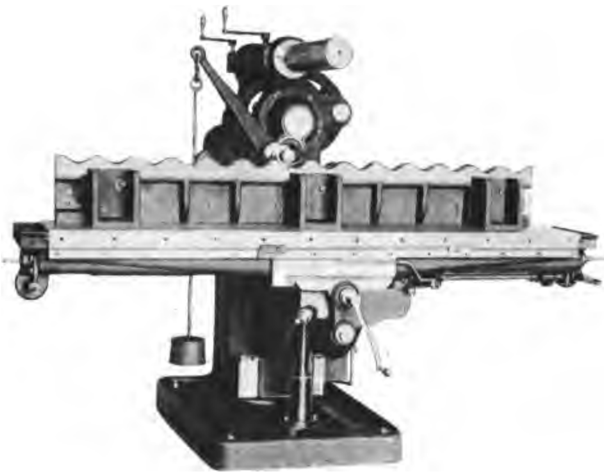


Fig. 32 — Irregular slots may be cut into plates or upon the edges of plates, and made to work in unison with a roll. Such an arrangement may be classed as a cam

METHOD OF PROCEDURE

Any word may be used; — for instance, the word "Cam," as in this example. The writing should be enclosed within a rectangle drawn tangentially to it, the horizontal line under the writing being the base of the diagram for Cam A. This base may be divided into any convenient number of divisions, in this case, twenty-five; and through these points of division, lines perpendicular to the base should be drawn across the rectangle, tangentially to, or intersecting the written word, as shown in the figure; and these must be lettered from right to left (the opposite direction to that in which the word is ordinarily written).

Continue the base-line of the rectangle indefinitely; assume on this line, a short distance from the rectangle, the point 0, of the base of the diagrams of motion, and at this point erect a perpendicular. This will correspond to the perpendicular in the rectangle which contains the starting-point 0 of the writing. In the figure this perpendicular is marked W.

The word "Cam" is written in such a way that the starting-point 0 in the writing is a certain distance above the base of the rectangle; project this point into the perpendicular erected at point 0 in the base of the diagrams, and this intersecting point, which is the same distance above the base-line, and also marked 0, is the

first point of the diagram of Cam A, which produces the up-and-down motion and manipulates the pencil.

To find the other points in this diagram, proceed as follows:

From point 0 in the writing the line forming the word intersects the perpendiculars to the base in points marked 1, 2, 3, etc., from 0 to the first turning of the curve is six divisions measured across the spaces of the rectangle. Through this distance the writing progresses upward and forward. Following the continuous line of the curve forward and backward through the different turning or tangential points throughout the word back to the starting-point 0, the distance measures eighty-four equal spaces, as shown on the lines below the rectangle. This is a number into which a circle may be easily divided. Lay off upon the base-line of the diagrams eighty-four equal divisions of any convenient length, and erect perpendiculars 1, 2, 3, etc. to correspond with the perpendiculars of the rectangle upon which points 1, 2, 3, etc. of the writing are found.

Intersect these perpendiculars by horizontal lines drawn from the corresponding points 1, 2, 3, etc. in the writing, and through each intersecting point thus found draw the irregular curved line of the diagram; this will complete the diagram of Cam A.

We are practically stretching out the curved line of the writing, the divisions of which correspond in number to the divisions of the base-line of the diagram.

To draw the cam from this diagram, draw a base-

circle (large enough to permit an easy rise and fall of the follower) which represents the base-line of the diagram, and divide it into the same number of divisions, eighty-four.

As this cam produces the up-and-down motion, its follower must work in an arc, X; hence another circle must be drawn through the fulcrum of the follower and divided into the same number of parts as the base-circle,—eighty-four, — to represent the different relative positions of the fulcrum and the cam. Since the follower must work in an arc, the Cam A should be ahead of Cam B; in this case it is 60 degrees. It might be placed behind it, but it is always better that the roll should trail. Number each of the eighty-four divisions of the fulcrum-circle, and number those of the base-circle, each 60 degrees ahead of the corresponding point in the fulcrum-circle. Take the length of the follower from the centre 0 of the fulcrum to the corresponding point 0 in the base-circle, and with this radius describe the arc of action X. Upon this arc of action measure the heights of the corresponding points above the base-line of the diagram. Repeat the same process at each of the eighty-four corresponding points around the circle. Revolve the points already found upon the arc X into the arcs just drawn, and through the points thus found draw the irregular curve of the cam. This will represent the centre-line of the roll upon the follower. Draw the roll in its different positions, and tangential to it the actual outline of the cam may be drawn.

Cam B produces the back-and-forth, or reciprocating motion.

As the pencil is controlled by Cam A, and does not move laterally, but up and down, it becomes necessary for the paper to move laterally; which movement is produced by Cam B. To draw this, proceed as follows:

Upon the perpendicular erected at 0, in the base-line of the diagram, set off twenty-five divisions exactly equal to the twenty-five divisions of the base-line of the rectangle, and letter them to correspond, making A, in the base-line of Cam B, to coincide with the base-line of Cam A. In this diagram only the actual changes in direction have been lettered, and they are also so marked upon the writing and upon the cam itself.

The starting-point 0 of the writing is upon the perpendicular W, of the rectangle, and is itself marked W. Therefore W in the diagram will be found upon the perpendicular erected at 0, which must contain the starting-points of the diagrams, and at the same distance above A in the base-line.

While the pencil controlled by Cam A progresses forward and upward, six divisions, Cam B must cause the paper to move in unison through six divisions horizontally to Q. Therefore Q in the diagram will be found at the intersection of perpendicular 6 from the base; and a horizontal line projected from Q in the perpendicular at 0. In the same way the line may be traced to the height of Z on 15, to L on 29, and so on back to W, the starting-point.

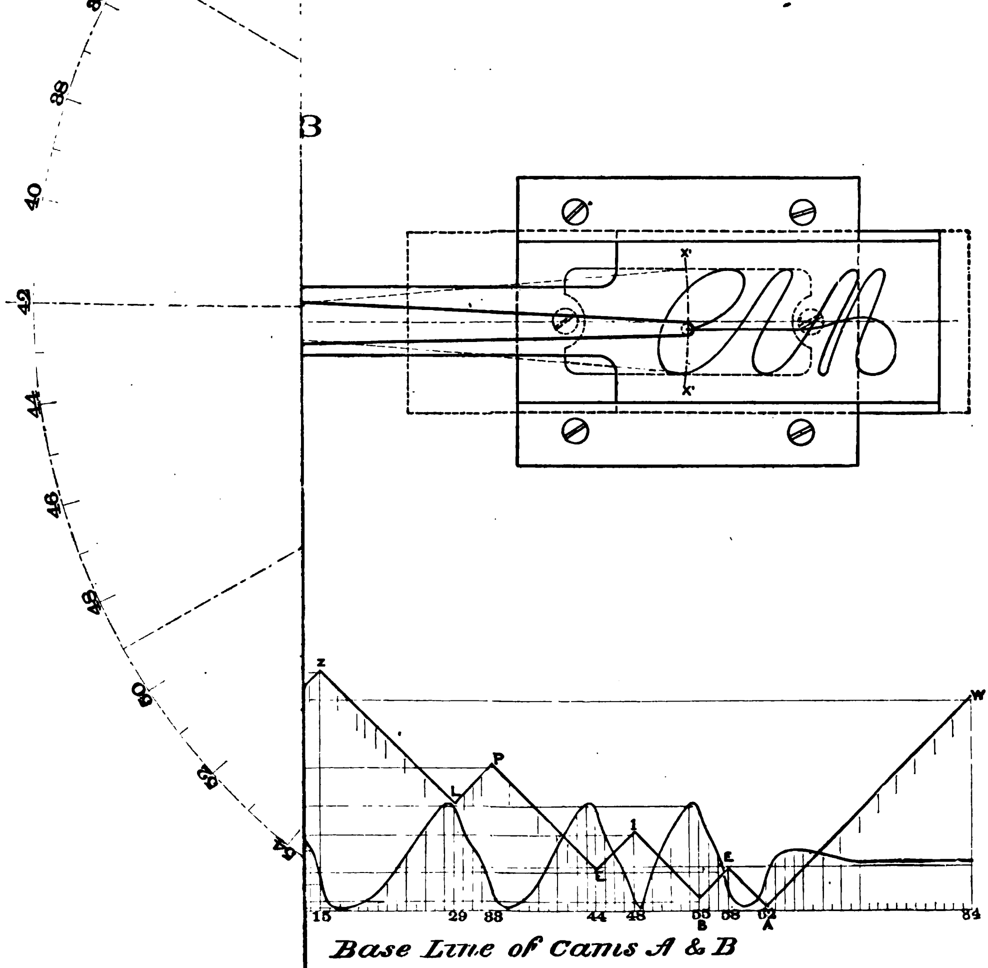
FIG. 34 — Writing Cam. Photograph of working model. See Fig. 33 for working drawing

Writing Cam

Designed and Built

by

George Jepson



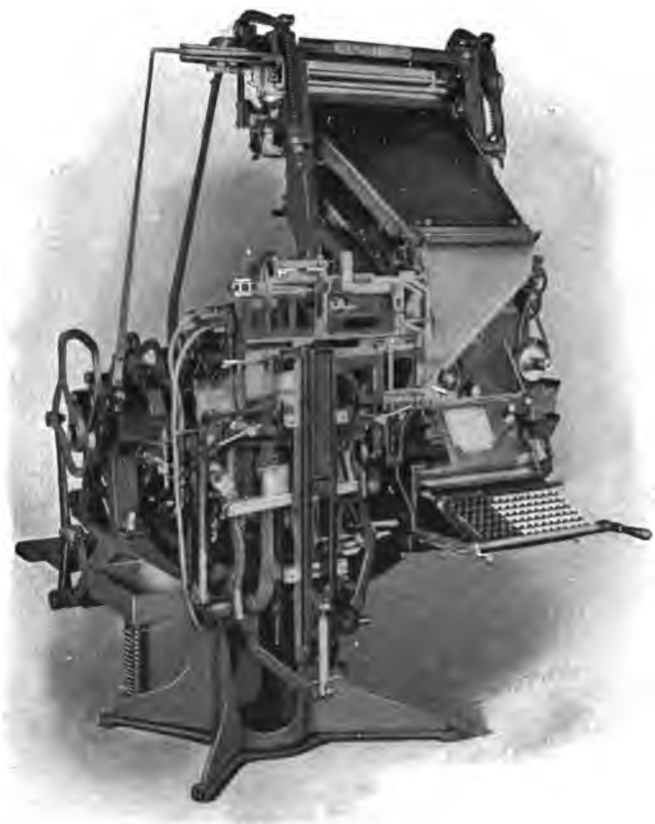


FIG. 36 — Linotype machine

Fig. 37—Showing the cams, part of the Linotype machine, enlarged. The Linotype machine is one of the wonders of this mechanical age. Without the aid of cams it could not accomplish such intricate work

Since this diagram is drawn upon the same base-line as the diagram of Cam A, it must also be drawn upon the same base-circle in the construction; but, since this cam produces the back-and-forth motion, its follower must move in a straight line containing the fulcrum; therefore, its starting-point must be in line with the fulcrum and marked by the same number, 0. To complete Cam B, proceed in a similar manner as with Cam A, taking the heights from the perpendiculars of the diagram and transferring them to the corresponding radial lines of the cam drawing, to obtain the points through which the centre-line of the roll may be drawn.

The time of any cam may be measured in degrees, or by any equal divisions of the circle, thus:—

360 divisions in degrees in a circle
84 divisions in diagram and drawing
$\frac{360}{84} = 4.28^\circ +$ in one division of diagram

The original drawing for this cam, Fig. 33, is thirty inches in length. The author recommends, in making a drawing of this or any similar cam, that it be made much larger than the illustration.